Stress Distortion Free Coating for High Resolution X-ray Mirrors

Completed Technology Project (2016 - 2020)

Project Introduction

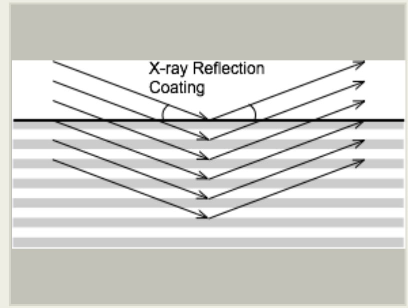
Most of X-ray optics research and development in the US is to build a high resolution, large collecting area and light-weight optic, namely an soft X-ray mirror for the X-ray Surveyor, as identified in the NASA PCOS astrophysics roadmap. One of the promising technologies is a segmented silicon X-ray mirror being developed at GSFC. The silicon mirror substrate is a thin (~400 μm thick or less) curved substrate. This substrate requires a heavy metal coating, such as iridium, for X-ray reflection. The coating layer has a residual stress which distorts the thin mirror substrates. The distortion amount increases as the coating layer thickness increases. This distortion greatly degrades the mirror angular resolution and prevents us from achieving the high resolution (~5”) that is required by X-ray Surveyor.

After the successful hard X-ray imaging observations by *NuSTAR*, the X-ray astronomy community has been wishing a next generation hard X-ray observatory with a greatly improved angular resolution < 10”, ~10 times better than *NuSTAR*. Such mission concepts have been discussed in many places and white papers were submitted for a Probe mission concept in the past. While such the Probe mission is being discussed in the US, the Japanese community also wants to have a new hard X-ray astronomy mission with the high angular resolution following up their *ASTRO-H* (*Hitomi*) mission and the mission called FORCE is being discussed. Now Japanese space program includes FORCE in their road map. Since the multilayer coating is a lot thicker (total thickness) than the soft X-ray coating, the mirror is expected to be severely affected by the distortion due to the residual stress. In fact, *NuSTAR* mirror was ended up with about 60” resolution while the substrate itself had <30” resolution performance before the coating.

For achieving the high resolution and the large collecting area with light weight discussed above, the segmented approach is the most promising one as a whole shell mirror will not likely be able to keep its shape, and its cost can be quite expensive. On the other hand, the segmented mirror is more susceptible to the residual stress than the whole shell. However, there is no clear path forward in research & development for removing the residual stress distortion, while the stress-free coating actually is the enabling technology for the high resolution mirror. We will study residual stress in the soft/hard X-ray reflection coating, i.e. single layer and multilayer coating, and develop a method to eliminate or minimize the residual stress distortion and keep the substrate figure intact after the coating.

Anticipated Benefits

All the future X-ray astronomy missions will likely be based on the segmented



X-ray reflection coating

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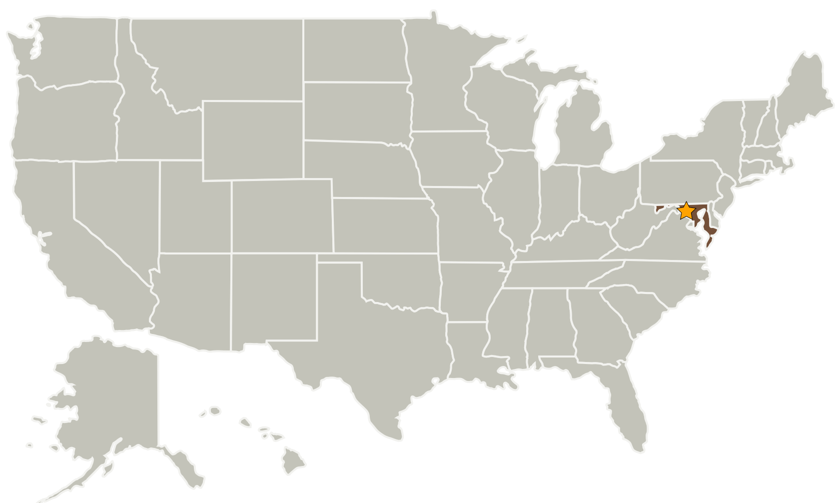
X-ray mirror approach, i.e. the silicon mirror being developed at GSFC, and they require the stress-free reflection coating either for soft/hard X-ray reflection in order to achieve the high angular resolution. However, no one can provide the coating without the substrate distortion as of today. In fact, this is identified as a technology to be developed in NASA's PCOS. X-ray Surveyor is under study and its STDT is working toward providing the 2020 NRC Decadal Survey Committee with inputs. Similarly people in the high energy community are working on the hard X-ray probe mission concept for the Decadal Survey. For these inputs, the stress-free coating study has to be done now to make the mission feasibility high. This work will allow us to produce high resolution mirror for the future NASA strategic or probe class missions.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
⭐Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations
Maryland

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Independent Research & Development: GSFC IRAD

Project Management

Program Manager:

Peter M Hughes

Project Managers:

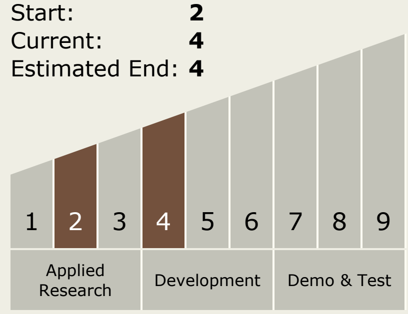
Keith M Jahoda
Emily L Wilson

Principal Investigator:

Takashi Okajima

Technology Maturity (TRL)

Start: **2**
Current: **4**
Estimated End: **4**



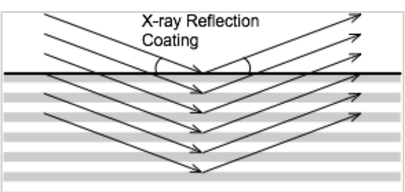
Project Transitions

October 2016: Project Start

September 2020: Closed out

Closeout Summary: We successfully mitigated stress distortion from a single l ayer coating on a thin substrate. We also achieved high angular resolution (~10 arcsec, HPD) at 30 keV with a Pt/C multilayer coated mirror using a relatively thi ck substrate. These coatings can be used to realize the future hard X-ray mirror s. The purpose of the Goddard Space Flight Center's Internal Research and Deve lopment (IRAD) program is to support new technology development and to addr ess scientific challenges. Each year, Principal Investigators (PIs) submit IRAD pr oposals and compete for funding for their development projects. Goddard's IRA D program supports eight Lines of Business: Astrophysics; Communications and Navigation; Cross-Cutting Technology and Capabilities; Earth Science; Heliophys ics; Planetary Science; Science Small Satellites Technology; and Suborbital Platf orms and Range Services. Task progress is evaluated twice a year at the Mid-ter m IRAD review and the end of the year. When the funding period has ended, the PIs compete again for IRAD funding or seek new sources of development and re search funding, or agree to external partnerships and collaborations. In some c ases, when the development work has reached the appropriate Technology Read iness Level (TRL) level, the product is integrated into an actual NASA mission or used to support other government agencies. The technology may also be license d out to the industry. The completion of a project does not necessarily indicate t hat the development work has stopped. The work could potentially continue in t he future as a follow-on IRAD; or be used in collaboration or partnership with Ac ademia, Industry, and other Government Agencies. If you are interested in part nering with NASA, see the TechPort Partnerships documentation available on the TechPort Help tab. http://techport.nasa.gov/help

Images



X-ray Reflection Coating
X-ray reflection coating
(https://techport.nasa.gov/image/40427)

Links

NASA Goddard Facebook
(https://www.facebook.com/NASA.GSFC)

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.2 Observatories
    - └ TX08.2.1 Mirror Systems

Target Destinations

Outside the Solar System, Foundational Knowledge

NASA Goddard Twitter
(https://twitter.com/intent/follow?screen_name=NASAGoddard)

NASA Goddard Website
(http://www.nasa.gov/centers/goddard/home/index.html)

Project Website:

http://sciences.gsfc.nasa.gov/sed/